Evaluation of Liquid Deicing Materials for Winter Maintenance Applications

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Kentucky Transportation Center
College of Engineering, University of Kentucky, Lexington, Kentucky

in cooperation with
Kentucky Transportation Cabinet
Commonwealth of Kentucky

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Research Report

KTC-21-20/SPR18-566-1F

Evaluation of Liquid Deicing Materials for Winter Maintenance Applications

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16. Abstract

Winter weather can often pose difficulties for transportation agencies as they work to clear roads of snow and ice quickly so that motorists can travel safely and efficiently. Kentucky has made efforts to maximize efficiency within its winter maintenance program by focusing on optimized equipment usage and personnel time management. In this study, KYTC evaluated anti-icers and how their performance compared to the current performance of brine and calcium chloride mixture. New brine additives claim to offer better results, but there is very little guidance about how to systematically evaluate new anti-icers. Researchers were tasked with developing a testing methodology that could be performed in a laboratory setting to evaluate an anti-icer's ability to "undercut", or break the bond between pavement and ice. Four products were tested, as well as evaluated for price per lane mile when the additives were diluted with brine. The report concludes with a brief analysis of the environmental impacts of the additives, including effects on infrastructure and biosystems.

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Executive Summary

In recent years, KYTC has made efforts to maximize efficiency within its winter maintenance program by focusing on optimized equipment usage and personnel time management. This project aims to evaluate and potentially optimize the materials that are being used within the program. KYTC currently uses a brine and calcium chloride mixture as an anti-icer. The material is spread on roads before a snow event and helps prevent a bond between the pavement and ice. KYTC's methodology is functionally effective and has been used for decades; however, many other ice-melting products have entered the market during that time period. New brine additives claim to offer better results, but there is very little guidance about how to systematically evaluate new anti-icers.

Researchers at KTC were tasked with developing a testing methodology that could be performed in a laboratory setting to evaluate an anti-icer's ability to "undercut", or break the bond between pavement and ice. The novel methodology was based on 1992 guidance from the Strategic Highway Research Program, and was modified to fit within KTC's laboratory parameters and to mitigate common issues that had been encountered in past studies.

Four anti-icing liquid additives were compared against KYTC's existing practice of using calcium chloride. The additives were Ice-B'Gone Magic, a 50/50 mix of distillers' byproduct and magnesium chloride; FreezGard Cl Plus, a magnesium chloride product that contains a sulfate corrosion inhibitor; Ice Ban 305, a mix of corn starch and magnesium chloride; and BioMelt AG64, a sugar alcohol blend made with beet byproducts. Each anti-icer additive was tested in the laboratory and photos were taken of the ice-undercutting process over thirty minutes. The photos were processed using Image J, which highlighted the undercut zones and converted the zones from a number of pixels to an area. A larger undercut area indicated a stronger anti-icer.

In terms of ice-undercutting ability, FreezGard Cl Plus was the best performer. Its average undercut area was about 60% larger than that of calcium chloride. The next best performers, Ice Ban 305 and Ice-B'Gone Magic, were about 10% stronger than calcium chloride. The performance of BioMelt AG64 was about equal to calcium chloride.

The cost of the anti-icers were evaluated for price per lane mile when the additives were diluted with brine in the distributor-recommended amounts. Calcium chloride, the current practice, remained the least expensive option when compared with the four new additives. FreezGard Cl Plus was about 50% more expensive than calcium chloride, while Ice Ban 305 was about 25% more expensive than calcium chloride. The costs of BioMelt AG64 and Ice-B'Gone Magic were 330% the cost of calcium chloride.

The report concludes with a brief analysis of the environmental impacts of the additives, including effects on infrastructure and biosystems. Any chloride products will present corrosion risk to bridges and pavements. The only product that does not contain chloride is BioMelt AG64 — overall, it is environmentally friendly, although its high sugar content could eventually intensify problematic bacteria growth in bodies of water. The other three additives contain magnesium chloride, which is known to be slightly less harmful than calcium chloride to bridges and pavements. In particular, Ice Ban 305 keeps salt particles closer to the surface of the pavements, which may slow the rate of corrosion and may also allow longer periods between reapplication. FreezGard Cl Plus contains a corrosion inhibitor, which should make it safer for pavements. Ice Ban 305 and FreezGard Cl Plus could be good potential substitutes for calcium chloride. Both products function with the existing application equipment and storage facilities, and could be easily integrated into KYTC's winter maintenance program.

Chapter 1 Introduction

1.1 Background

Winter weather can often pose difficulties for transportation agencies as they work to clear roads of snow and ice quickly so that motorists can travel safely and efficiently. Kentucky receives about fifteen to twenty inches of snowfall each year.[1] The Kentucky Transportation Cabinet (KYTC) typically expends between $40 million and $80 million per year on snow and ice removal and road treatment, including equipment, materials, and personnel.[2] In recent years, KYTC has made efforts to maximize efficiency within its winter maintenance program. Previous research projects have uncovered efficiencies in equipment usage and personnel time management by optimizing snowplow routes in each transportation district. Now, KYTC is interested in evaluating its program with regard to the materials applied to roadways. There are many ice-melting products on the market, but they have not been compared and evaluated. KYTC has proposed an in-depth assessment of anti-icing materials and contracted the Kentucky Transportation Center (KTC) to perform the work.

1.2 Chemistry

Although they vary widely in performance, all ice melters work in generally the same way — they depress the freezing point of ice or snow and turn the mixture into a liquid or semi-liquid slush. There are two general classes of ice melters: chemical salts and fertilizer products. Solid chemical salts bore through ice or snow and form a strong brine solution. This brine spreads under the ice or hard-packed snow and “undercuts”, breaking the bond to the surface. Once loose, the ice or snow is easily removed by mechanical means. Fertilizer products work in much the same manner, though they do not form a brine. They are soluble in water and the resulting solution acts by depressing the freezing point of snow and ice.

It is much easier to prevent ice from forming rather than melting it later. The same material used for melting can be applied in anticipation of ice or snow, preventing future snow or ice from bonding to the surface. When materials are used in this way, it is referred to as an anti-icing material. Both solid and liquid deicers can be used as anti-icers. Liquid additives are often added to the anti-icing material as well. These liquid additives may be chemicals or agricultural byproducts and are meant to increase the effectiveness of the material.

1.3 Current Practice

The goals of KYTC’s snow and ice control program are to:

- Provide adequate traction on road surfaces
- Promote safe and timely driving conditions
- Provide uniformity of pavement conditions within the route priority system
- Account for economic and environmental factors

The ability to meet these goals depends at least partially on the materials that are chosen to treat the roads.

In Kentucky, as in most states, the response to winter storms usually has two phases. First, if conditions allow, roads are pre-wet with an anti-icing liquid before snowfall begins. Once snow is on the ground, trucks begin plowing the roads and treating them with solid salt.

For anti-icing, KYTC currently uses a mixture of brine and calcium chloride. This three-ingredient combination contains water, 23.3% sodium chloride ($NaCl$), and 5% liquid calcium chloride ($CaCl_2$). The sodium chloride brine is created at a 23.3% solution because that is the concentration at which salt brine has the lowest freezing point: -6 degrees Fahrenheit. The liquid calcium chloride is created at a 32.2% concentration. Calcium chloride melts ice down to approximately -25 degrees Fahrenheit. Calcium chloride is fast acting and generates additional heat as it dissolves. Additionally, brine forms easily because it has hygroscopic properties that cause it to attract moisture from its surroundings.

According to industry standards, the brine and calcium chloride mixture should be spread at a rate of about one ounce per square yard. It is applied at temperatures between 20 and 35 degrees Fahrenheit and should be allowed time to dry before precipitation begins. During recent winters, more than a million gallons each of brine and calcium chloride were used for pre-wetting and anti-icing. For extreme winter weather conditions, as much as 2.5 million gallons of brine has been used in one season.[2]

1.4 Problem Statement

Kentucky has used the same methodology for decades to treat roads during inclement weather. Over that time, many other products have been introduced in the market. Evaluating new liquid additives could optimize Kentucky's snow and ice removal process.

New brine additives claim to offer better results. However, they have not been rigorously tested and therefore their effectiveness and overall value for improving snow and ice control is unknown. There are also logistical issues associated with the use of additives, such as the need for additional storage, as well as concerns about the safe handling and distribution of these additives at KYTC's 124 snow and ice maintenance facilities.

To that end, the objectives for this research were to evaluate the effectiveness, costs, and feasibility of incorporating new liquid anti-icing materials into the Cabinet's winter maintenance program.

Chapter 2 Literature Review

The research team reviewed relevant literature and current agency and industry practices on snow and ice removal. The review achieved three main purposes:

1. Determine products that might be of interest and understand their ice-melting capabilities
2. Gain insight into common road treatment practices by surveying several other state departments of transportation (DOTs)
3. Find or develop a testing method for products of interest

2.1 Products

There are hundreds of anti-icing products on the market. For the purpose of this research, anti-icing additives refer to the chemical products or commercial blends that are added to brine and applied before a winter storm. Typically, anti-icing additives are added to a brine solution in percentages that are recommended by the distributor. Agencies can choose additives that are non-proprietary chemical products or they can purchase trademarked commercial mixes. This section will detail both types of products and review some of the most common products currently offered.

Sodium chloride, also known as rock salt, is considered the original ice-melting product. It melts ice in temperatures as low as -9 degrees Fahrenheit, and KYTC uses this as its main ice melting product. There are some major drawbacks to using sodium chloride — it damages concrete, asphalt, stone, and brick, quickly leading to road and bridge degradation. Sodium chloride that leaks into soil can adversely impact groundwater and nearby biosystems.[3]

Using calcium chloride as an ice-melter or additive is common practice across the United States. Calcium chloride can melt ice to a temperature as low as -29 degrees Fahrenheit.[3] It is unique among other ice melters because, while most other products rely on their surroundings for heat to generate a reaction, calcium chloride generates its own heat as it dissolves. Additionally, brine forms easily because it has the ability to attract moisture from its surroundings.[4]

A fairly common alternative to calcium chloride, magnesium chloride ($MgCl_2$), is marketed as more environmentally friendly and less corrosive. Its lowest effective temperature is around -15 degrees Fahrenheit.[3] It is similar to calcium chloride in that it is exothermic and can attract moisture from its surroundings.[5] Magnesium chloride is slightly less harmful to pavements than sodium chloride and calcium chloride.[6] There are many commercial blends that contain magnesium chloride, including some that were tested in Kentucky's research.

Because so many of the current practices are harmful to the environment, some manufacturers have begun introducing organic materials in order to balance the risk. These materials often come from agricultural processes (referred to as "agro-based" or "bio-based") and may pose less of an environmental threat.[7] Most agro-based products contain sugar in some form. Many agricultural processes produce sugars, sugar alcohols, and/or carbohydrates as byproducts. Popular sugar-based ice melters that are currently on the market include beet juice, corn syrup, vodka byproduct, grape extract, and glycerin.[8] Sugars depress the freezing point of water further than chloride salt alone, resulting in a longer working time, lower application rates, and reduced corrosion.[9] Additionally, sugar products are usually sticky, helping to ensure that salt products cling to the surface and stay on the road, thereby reducing runoff that can damage plants and aquatic environments.[10]

Corn starch was first introduced as an ice-melter in 1998. Corn starch increases the viscosity of fluids as they are sprayed on the highway and forms a water gel structure on the road. The gel provides a "platform" in the top portion of the pavement, helping retain salt or brine near the surface of the roadway for an extra two to four hours. This reduces the need for subsequent salt treatments.[11] There is some evidence that suggests the corn starch may degrade into sugar alcohols that can reduce the freezing point of ice further than salts alone.[9] An added benefit of corn starch additives is that they have no effect on the environment; they can be used near sensitive environmental areas and near water.[12]

2.2 Survey of Other States

In order to better understand which public agencies are using blended liquid products for anti-icing, KTC researchers prepared a survey to assess current practices across the country. The survey was distributed electronically to all members of a listserv group established by the AASHTO Winter Maintenance Technical Services Program (SICOP). There are approximately 600 subscribers on the listserv representing metropolitans, counties, state DOTs, and vendors. The survey generated twelve usable agency responses, which are summarized in the following paragraphs and tabulated in Appendix A.

The survey included eight questions about products used, the selection process, previous research performed, and the associated costs to the agency. Of the twelve respondents, six of them use magnesium chloride, five use calcium chloride, three use beet juice products, three use potassium acetate, one uses calcium magnesium acetate (CMA), and one has used potato byproduct. In addition, five agencies indicated that they use one or more commercially prepared liquid additives. Those were Agua Salina (chloride blend), Clear Lane ($MgCl_2$), Shield GLT (corrosion inhibitor), FreezGard ($MgCl_2$ and corrosion inhibitor), Meltdown Inhibited ($MgCl_2$ and corrosion inhibitor), ThawRox ($MgCl_2$ and carbohydrate), Caliber (corn product), Ice Ban (corn starch), GeoMelt (beet juice), Beet Heet (beet juice), and Magic Minus Zero (carbohydrate). For those agencies that blend additives into a mixture (rather than use it undiluted), they almost always blended with a 23.3% solution of sodium chloride brine, though they occasionally mixed with calcium chloride.

Regarding the selection process, agencies said they made their choices based on two main reasons: 1) the desire to improve the effectiveness of brine at lower temperatures, including ensuring the brine did not freeze in the storage or distribution tanks, and 2) the desire to inhibit the corrosive nature of brine or other ice-melting products. Only one agency had conducted a formal research project on the products. Many states referenced the Pacific Northwest Snowfighters (PNS) and their catalog of approved winter maintenance products, the Qualified Products List (QPL). Clear Roads assumed control of the QPL in 2018, but this survey was sent out in 2017 when it was still under PNS.

Costs of the liquid additives varied significantly. In general, the cost to produce brine ranges from $0.08 to $0.45 per gallon. The cost of the additives ranged from $0.26 to $2.48 per gallon. Once blended into the appropriate dilutions, the mixtures cost $0.12 to $0.34 per gallon.

The review of survey responses assisted the study advisory committee's decision on the products to pursue for laboratory testing. The final choices are summarized in Section 3.1.

2.3 Testing Methods

While there are a wide variety of anti-icing and de-icing products in use, many agencies were not able to provide clear reasoning for their choices. This is not surprising: the products are very difficult to test and form conclusions about their potential use. There is no uniform testing procedure in place that allows agencies to make informed decisions about their anti-icing and de-icing products. In fact, there is a remarkably small amount of literature regarding potential testing methodologies. Testing methods vary, as do the objectives. Some of the tests have been performed in a lab, others have been performed in the field, and other methods are strictly theoretical. In some cases, researchers performed tests on proprietor blends and had to keep some information undisclosed, which makes it nearly impossible for other researchers to repeat their experiments or modify them appropriately. However, the research on prior testing and suggested methods informed KTC's ability to develop their own testing protocol. The rest of this section describes the requirements that should be met when testing a new material.

First, it is important to ensure that all ice melters have been evaluated and approved by the appropriate entity. In this case, Clear Roads approved all the ice melters that KYTC was interested in testing. Clear Roads is a national research consortium focused on rigorous testing of winter maintenance materials, equipment, and methods for use by highway maintenance crews. Their list of approved ice melters is the Qualified Products List (QPL). Products selected for inclusion on the QPL must pass a series of tests for friction, corrosion, and chemical and toxicological properties, and meet environmental and health standards. It is important to note that inclusion on the QPL is not based on performance as an ice-melter; Clear Roads simply tests for composition and safety.[13]

Next, an agency should decide what type of ice melting capability they are interested in testing. Ice melters can be evaluated in terms of their melting ability, their ice undercutting ability, or their ice penetration ability. Because KYTC was interested specifically in anti-icing agents, the most important trait was a product's ice undercutting ability, or its ability to disrupt or prevent the bond between ice and pavement. The Strategic Highway Research Program (SHRP) provides guidance for various ice melting tests in its 1992 document: *Handbook of Test Methods for Evaluating Chemical Deicers.* The recommended ice undercutting test measures the area of the brine film formed between a layer of ice and a substrate material. Various substrates can be used, but the substrate of choice for deicer evaluation in the lab is concrete-based because of its smooth surface. In the recommended test, a 1/8-inch thick layer of ice is frozen slowly from the bottom upward. This mimics the way ice forms on cold pavement and it also ensures the ice is clear so melting measurements can be accurate. Then, small cavities are created in the ice, into which weighed samples of dyed anti-icer are inserted. The dyed anti-icer spreads out underneath the ice in a radial manner. Photographs taken at time intervals track measurements of the melted area. The SHRP Handbook acknowledges that the recommended test method produces very symmetrical melted areas which may be considerably smaller than undercut areas obtained with less strongly bonded or less perfect ice formed under natural conditions. Since the SHRP Handbook tests had not been performed at the time of publishing and were only theoretical, they lacked some of the troubleshooting measures that may have come up during testing. Nevertheless, the methodology served as an excellent starting point for KTC to develop and refine their own lab testing methodology.[14]

KTC researchers also examined the work of several other agencies that had performed ice melting tests, including some tests based on the SHRP Handbook methodology and other tests that were unrelated. The predominant takeaway from others' research was that testing deicers in the laboratory is an excellent way to compare the relative performance of deicers, but the exact values from laboratory tests generally do not correlate directly with actual field performance.[15] Still, the products' relative performance tends to remain the same in the field as it was measured in the laboratory. For KYTC, laboratory testing is adequate for the purpose of comparing deicer products and determining the best performer.

During effective laboratory testing, the parameters that were controlled were: air temperature, pavement temperature, relative humidity, pavement type, and uniform snow/ice. Ideally, traffic and plowing simulations should also be included during testing, but that is not always possible. The environment has more of an effect on anti-icing performance than traffic does. Therefore, controlling as many environmental parameters as possible is more important than simulating traffic and plowing.[15]

According to a 2010 Clear Roads research study, SHRP's ice undercutting test methodology is the most representative of actual field performance of deicers, while also maintaining several benefits of a standard laboratory test.[15] In fact, two concurrent 1992 experiments tested the connection between ice undercutting and disbondment (such as shoveling or plowing) and concluded that in most cases, the percentage of ice removed from the pavement is equal to the percentage of undercut area.[16,14] Thus, SHRP's simple ice undercutting test provides enough indication of the disbondment characteristics of anti-icers.

In 2009, Shi et al. performed SHRP's ice undercutting test for solid and liquid products. They took digital photos and then used Adobe Photoshop to measure the undercut area. Exact measurements were calculated by counting the number of pixels of dyed area. This study suggested that 32 degrees was the optimal temperature for the ice undercutting test. They found that the SHRP methodology was more useful for liquid deicers than solid deicers. The solid deicers often separated from the dye; the dye would spread across the surface of the substrate without the deicer, giving the appearance of undercutting without any true melting.[17]

Chapter 3 Methodology

3.1 Products of Interest to Kentucky

Performing the literature review and agency survey introduced the research team to a variety of different anti-icing and deicing products. After consulting with Kentucky Transportation Cabinet officials, five products were selected for testing. The products comprised an assortment of commercial blends that are readily available in the state or that have been recommended by other agencies. With the hope of finding environmentally-friendly options, the team also chose some bio-based products. The products that were chosen were:

- BioMelt AG64, a sugar alcohol blend made with beet byproducts
- FreezGard Cl Plus, a magnesium chloride product that contains a sulfate corrosion inhibitor
- Ice-B'Gone Magic, a 50/50 mix of distillers' byproduct and magnesium chloride
- Ice Ban 305, a mix of corn starch and magnesium chloride
- Calcium chloride, KYTC's current practice

BioMelt AG64

BioMelt AG64 is a completely organic sugar alcohol blend made with beet byproducts. It is a dark, sticky liquid that can be applied to roads as an anti-icer or mixed with rock salt to form a deicer. Beet juice depresses the freezing point of water further than rock salt alone. Specifically, BioMelt is effective to -40 degrees Fahrenheit. Because BioMelt AG64 is sticky, it helps keep products on the road and reduces runoff waste; the manufacturer asserts that this can reduce anti-icer application rates by 30-50%, compared to typical chloride deicers.[18]

FreezGard Cl Plus

Magnesium chloride is a common base for deicers and anti-icers. One commercial product, FreezGard Cl Plus, contains 30% magnesium chloride as well as a sulfate additive. The sulfate additive acts as a corrosion inhibitor without lessening the melting capability of the magnesium chloride. This makes FreezGard Cl Plus safer for pavements and bridges. FreezGard Cl Plus has a working temperature of about 0 degrees Fahrenheit.[19]

Ice-B'Gone Magic

"Ice-B'Gone Magic" (referred to as IBG Magic or also known as Magic Minus Zero) is 50-60% magnesium chloride combined with 40-50% distiller's byproduct. The byproduct is a grain or sugar solution that is produced during the production of vodka and rum. These liquid byproducts are added to the salt or brine in specific proportions to significantly lower the working temperature of chloride salt. This allows a longer working time, lower application rates, and reduced corrosion. IBG Magic's freezing point is -45 degrees Fahrenheit; when it is used as a salt additive, the mixture's freezing point is -35 degrees Fahrenheit.[20]

Ice Ban 305

Ice Ban 305 (recently rebranded to Torch IB) is a corn starch-based anti-icing additive which also contains 25% magnesium chloride. Ice Ban 305 is a clear, colorless liquid with a freezing point of -67 degrees Fahrenheit. The blend was originally introduced for use in sensitive environmental areas. Initial application rates are similar to other anti-icers and deicers, but the corn starch helps the product stay on the road longer, thereby reducing the reapplication rate.[21]

Calcium chloride

Calcium chloride is the most common anti-icer in use in the United States; KYTC has used it for decades. Calcium chloride is fast-acting, efficient, and works in temperatures as low as -29 degrees Fahrenheit.[3] For KTC's laboratory experimentation, calcium chloride was used as a control to compare the innovative products to an existing baseline.

3.2 Laboratory Methodology

The purpose of laboratory tests was to measure the ice undercutting ability of the five identified anti-icers. The anti-icers were not diluted with brine; this ensured that data would show the melting capabilities of the anti-icer itself. The laboratory test developed by KTC researchers was loosely based on the SHRP H205.6 test, which "tests the ability of a deicer to melt ice at the interface between a layer of ice and a pavement substrate." The SHRP H205.6 testing methodology was published in 1992, but was only theoretical and had not actually been performed. KTC researchers adapted the SHRP testing methodology to fit within constraints of their laboratory, and added some modifications to increase effectiveness.

For those wishing to repeat the experiment, a full methodology can be found in Appendix B. In brief, the laboratory test involves the following steps:

1. Create a smooth pavement substrate (concrete) with dimensions of about 4 inches by 8 inches.
2. Freeze 1/8-inch layer of ice on the substrate from the bottom up, mimicking the formation of ice on roads and ensuring clear ice. A bottom-up freeze can be achieved by freezing the substrate at a very low temperature before applying water, then using a gentle heat source directed at the surface of the water.
3. Form small cylindrical cavities in the ice using a heated aluminum rod gently pressed onto the ice surface. Remove the melted water from the cavities.
4. Use a syringe to place a small quantity of dyed liquid anti-icer within each ice cavity. The anti-icer will make contact with the substrate.
5. Take photos at regular intervals as the dyed anti-icer disrupts the bond between pavement and ice and spreads out beneath the ice.

In this test, ice melting occurs in part by enlargement of the cavity, and in part by melting at the interface between ice and substrate. Both are captured by taking photos from above; the dyed area increases over time as the anti-icer works.

The tests are performed at 30 degrees Fahrenheit. This temperature was chosen in an effort to mimic Kentucky's winter weather: average low temperatures in January range from 23 to 28 degrees.[1] According to KYTC's snow and ice program, anti-icers are applied at between 20 and 35 degrees. 30 degrees was within this range but warm enough to still see significant, measurable melting. The relative ambient humidity for all tests was between 86% and 87%.

It is important to note that this test does not necessarily represent conditions that would exist under normal field application conditions. In practice, anti-icers would be applied before a snow event and therefore prevent a bond from forming between the pavement and the snow or ice. In a laboratory setting, however, ice must exist before melting can be measured. The laboratory test serves as a valuable tool to accurately estimate ice-undercutting ability, even though it occurs at a different point in the process than it would under actual winter weather conditions.

3.3 Data Processing

The product of the laboratory work was a collection of photos taken at regular intervals. Figure 3.1 shows an example of a photo taken to measure an anti-icer's undercutting ability. During testing, a ruler was placed next to the ice so that it was level with the surface of the substrate and within the frame of the photograph. Using the ruler as a conversion factor between length and number of pixels, researchers were able to determine the exact area of melted ice for each photo. Researchers used Image J, an image processing program designed for scientific images. Within Image J, a line was drawn between points on the ruler and that distance was defined to effectively create a scale for the image. Then, the image was converted to an RGB color image; this helps the user identify what colors are in the image. By manipulating saturation parameters, the Image J user can highlight the zones of the ice that were undercut by the dyed anti-icer, as shown in Figure 3.2. Then, that zone's number of pixels is converted to an area using the previously-established scale. Area outlines are drawn, as shown in Figure 3.3. The result of photo processing with Image J is a set of area measurements that represent the amount of ice that was undercut by the anti-icer used.

Figure 3.1 Example of Ice Undercutting Documented in Lab

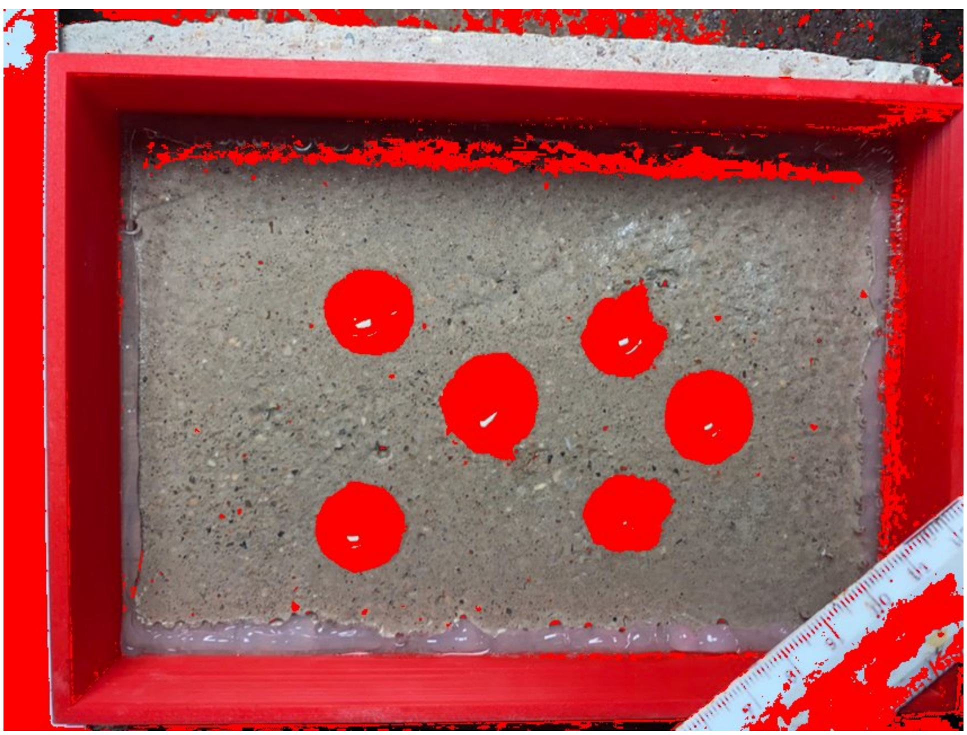

Figure 3.2 Image J Color Manipulation of Undercut Areas

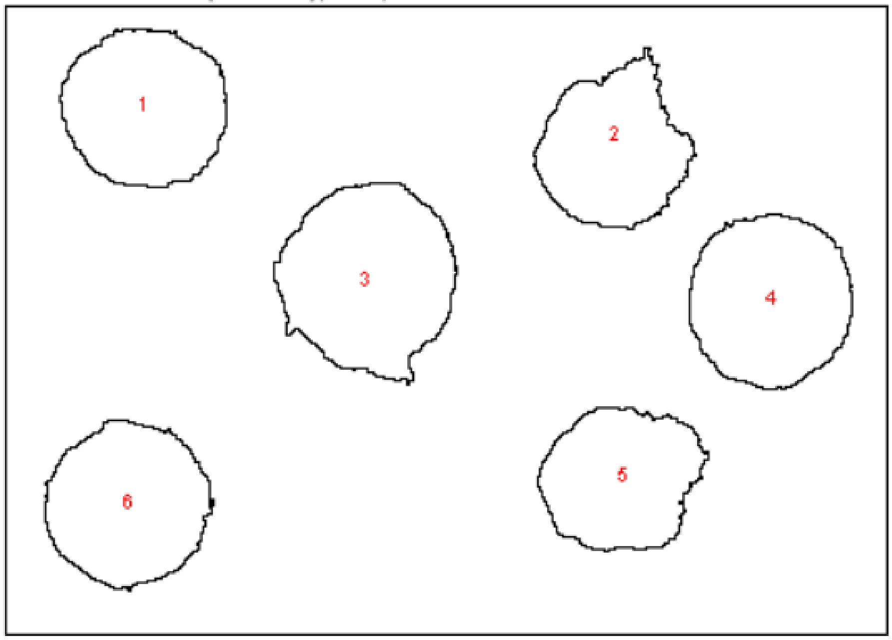

Figure 3.3 Areas Identified by Image J

3.4 Field Methodology

The original design for this research included incorporating field tests as well as laboratory tests. Lexington, Kentucky received so little snow during the project period that robust field testing of the anti-icer products was not possible. A field methodology was developed and tested only one time in January 2019. Due to the small amount of data, conclusions cannot be drawn from field testing and would benefit from future study. The field test methodology is outlined below.

1. Delineate sections using cones and label each one with the appropriate product name. (KTC researchers used areas that were 128 feet by 11 feet because it matched trailer parking spots that were already there.) Include an untreated segment to serve as a control.
2. Mix products according to distributor recommendations. Put each blend in a five-gallon portable agricultural pressure sprayer.
3. Spray anti-icing blends on corresponding areas about 24 hours in advance of a predicted snow event. Spray streams should be spaced at four inches apart to simulate the pattern of the anti-icing spray bars in use by KYTC.
4. As the snow begins, record depth of snow and ground temperature every 30 minutes. Also take pictures from above using a ladder. Note any observed differences between the test segments.
5. Corresponding to the observation times, perform a "shovel test" by pushing a shovel in one pass along several areas of each segment. Determine if it is harder or easier to shovel than the untreated area. (This will be somewhat subjective.) Photograph results of the shovel test.

Chapter 4 Results

4.1 Undercutting Ability

The main objective of the laboratory study was to determine the ice-undercutting ability of each anti-icer. The anti-icers were tested on their own, not mixed with brine. Over a period of thirty minutes, the anti-icers disrupted the bond between ice and pavement substrate, creating zones of measurable undercut areas. Measurements of the undercut areas were taken at designated intervals, with a total of 1495 data points collected across the five products tested. The undercut areas were compiled and averaged for each anti-icer, as shown in Figure 4.1.

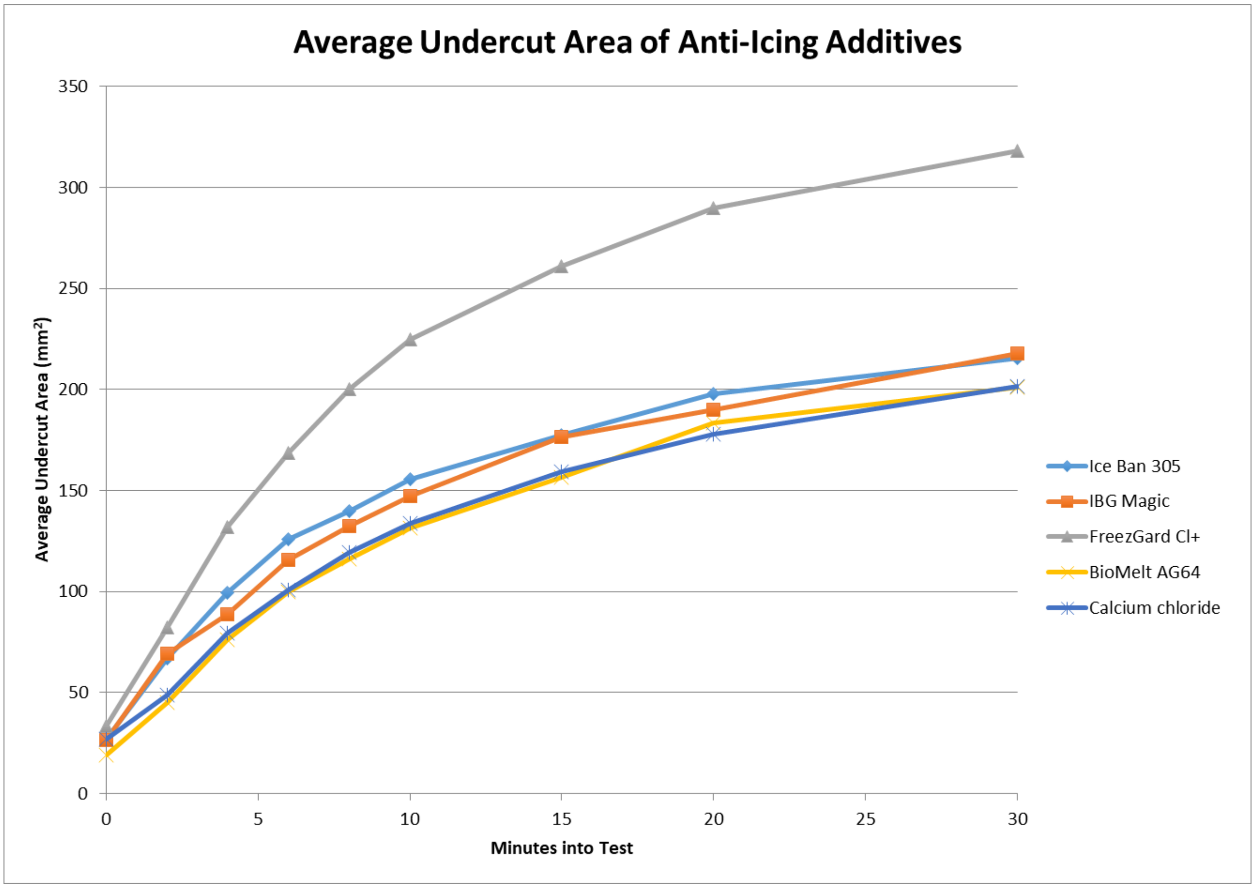

Figure 4.1 Average Undercut Area of 5 Anti-Icing Additives

Of the undiluted anti-icers, FreezGard Cl Plus performed the best. Each application undercut an average area of 318.22 square millimeters. FreezGard Cl Plus started disrupting the bond between ice and substrate within the first two minutes and continued to spread out over the substrate at a fairly steady rate. By the end of the thirty-minute test, it had undercut an area about one and a half times as large as the next best performer.

IBG Magic and Ice Ban 305 were second in terms of performance, and they performed equally well, creating average undercut areas of 217.69 square millimeters and 215.70 square millimeters, respectively. When the tests ended at thirty minutes, IBG Magic had undercut more area; however, it is not possible to determine which would have performed better over a longer period of time.

Calcium chloride and BioMelt AG64 performed comparatively. Calcium chloride undercut a total average area of 201.64 square millimeters. KYTC's current anti-icer, calcium chloride, is only about 60% as effective as FreezGard Cl Plus. BioMelt AG 64 undercut a total average area of 200.99 square millimeters. BioMelt AG64 had a lower starting point than all other test subjects, possibly because its viscosity is higher and it was not able to immediately start spreading out the way the other liquids did.

4.2 Cost

Since the cost of a product is an important consideration to the state, the anti-icing blends were evaluated for their price as well as for performance. The cost of commercial products can vary depending on the location where it is used and the amount of product required. The following prices were determined by using Frankfort, KY as the delivery point and by requesting a minimum of 4,500 gallons per order (which is a typical minimum). Exact vendor quotes with more details are attached in Appendix C.

- Calcium Chloride: $0.95/gallon
- FreezGard Cl Plus: $1.29/gallon
- Ice Ban 305: $1.81/gallon
- BioMelt AG64: $2.10/gallon
- IBG Magic: $3.00/gallon

Costs should also be evaluated in terms of the distributor-recommended dilution. These anti-icing materials are usually not used by themselves, but as additives to brine. The cost of brine is $0.12 per gallon. Table 4.1 summarizes the additive costs along with the distributor-recommended dilutions and associated cost of the mixture. In the last column, a cost per lane mile was calculated using KYTC's standard practice of 45 gallons per lane mile.

Table 4.1 Costs of 5 Anti-Icing Additives

Anti-Icer	Cost Per Gallon	Recommended Dilution	Cost Per Gallon When Diluted with Brine	Cost Per Lane Mile
Calcium Chloride	$0.95	5%	$0.16	$7.27
FreezGard Cl+	$1.29	10%	$0.24	$10.67
Ice Ban 305	$1.81	5%	$0.20	$9.20
BioMelt AG64	$2.10	20%	$0.52	$23.22
IBG Magic	$3.00	15%	$0.55	$24.84

Calcium chloride solution, the current product, is the most cost-effective option for both cost per gallon or cost per lane mile. FreezGard Cl Plus and Ice Ban 305 are the next most economical additives. Per lane mile, FreezGard Cl Plus is about 1.5 times the cost of calcium chloride, and Ice Ban 305 is about 1.25 the cost of calcium chloride. When comparing FreezGard Cl Plus and Ice Ban 305 to each other, it's important to note that the price per gallon of FreezGard Cl Plus is less than Ice Ban 305, but the distributor-recommended concentration is stronger; therefore, the price per mile of FreezGard Cl Plus is slightly higher than that of Ice Ban 305. BioMelt AG64 and IBG Magic have high gallon prices *and* their concentration in solution is higher, so they ultimately have the highest cost per lane mile.

This cost analysis concludes that FreezGard Cl Plus and Ice Ban 305, two top performers in terms of melting, could both be adequate substitutions for calcium chloride without exorbitantly raising the cost of winter maintenance operations.

4.3 Application and Storage

A central factor in choosing an anti-icer is its ease of application and efficiency of storage. If KYTC plans to optimize their snow and ice program by selecting a new anti-icing product, it must be compatible with the existing application equipment and storage facilities. In Kentucky, salt, brine, and calcium chloride are held at KYTC district and county highway maintenance facilities. Each site has barns with the capacity for one million gallons of calcium chloride solution and one million gallons of salt brine. The tanks that hold the material are made of carbon steel with an epoxy-based interior coating and a durable, high-quality coating on the exterior. All four anti-icing alternatives can be used with existing equipment. Their complete Product and Safety Data Sheets can be found in Appendix D, and the important notes are summarized in the following paragraphs.

FreezGard Cl Plus is stable under normal conditions. It can be stored in the usual facilities, but it needs to be agitated regularly. At temperatures under zero degrees Fahrenheit, solids may start to precipitate out of solution. (This occurs in calcium chloride as well, but at a higher temperature of about 32 degrees Fahrenheit.) Application equipment should be rinsed daily with water to prevent buildup of solids. Aluminum storage tanks or hauling equipment should not be grounded. Agencies should take care to avoid contact between FreezGard Cl Plus and acids or strong oxidizing agents. Over-application of FreezGard Cl Plus results in slippery surfaces, so care should be taken to apply it in the correct amounts.[22]

IBG Magic is similar to FreezGard Cl Plus in that over-application can result in extremely slippery surfaces. IBG Magic is somewhat corrosive and will attack aluminum, brass, and some soft metals. Contact with strong oxidizers should be avoided.[23]

Ice Ban 305 is stable and nonreactive. According to its Safety Data Sheet, there are no conditions to avoid other than excessive moisture, which is a typical precaution for most ice melting products. Periodic recirculation is suggested during long-term storage.[24]

BioMelt AG64 is stable and unreactive. There may be minor corrosion when it comes in contact with light metals. BioMelt AG64 has a 100% shelf life, making it economical over time.[25]

4.4 Environmental Effects

The research team also evaluated the impact that these anti-icers may have on their environment. Environmental impacts can be discussed in terms of the effect on pavements and the effect on biosystems.

Three of the four novel products that were tested (FreezGard Cl Plus, Ice Ban 305, and IBG Magic) contain magnesium chloride. In general, magnesium chloride is less corrosive than calcium chloride and therefore less harmful on pavements.[6] However, it can increase the amount of water that seeps into the concrete's pores and create damage through freeze-thaw expansion. Mostly, this is only a hazard for pavements that are less than one year old.[26] In FreezGard Cl Plus, there is an additional corrosion inhibitor that reduces this risk even more. Ice Ban 305 contains corn starch, which may slow the rate of corrosion. The fourth novel product, BioMelt AG64, does not contain any chlorides. It poses no threat at all to pavements.

In terms of biological environmental impact, the five anti-icers present varying degrees of risk. Most importantly, none of these are considered hazardous to the environment or toxic to wildlife in the amounts they are meant to be applied. But risks may be present over a long period of time as chemicals disperse and enter waterways or seep into groundwater. Of the five anti-icers that were tested, calcium chloride is the most harmful. Calcium chloride has a defoliating effect on trees and other plants.[27] If it leaches into waterways, it reduces the water's available oxygen levels which can pose a threat to aquatic life.[3] FreezGard Cl Plus is considered an environmentally safe substitute. The product itself and the process used to harvest the minerals are more environmentally friendly than calcium chloride.[22] Ice Ban 305, the corn starch anti-icer, is safe because it was initially developed for use in sensitive environmental areas where significant reductions in phosphorus and nutrients are necessary to protect a fragile ecosystem.[21] IBG Magic is designated by the EPA as a DfE (Design for Environment) product. It received this designation because, compared to many other anti-icers, it is less harmful to plants and aquatic life.[23] BioMelt AG64 is considered good for the environment because it does not contain chlorides and its sticky texture helps reduce runoff. However, if large quantities of it enter bodies of water, the high amounts of sugar can cause increased levels of bacteria.[28]

It is difficult to quantify the exact environmental impact and risks of using these commercial products, but researchers can conclude that any one of the four novel anti-icing blends has certain advantages over calcium chloride. Overall, the best way to manage environmental impact is to minimize the amount of road salt used. Adding a liquid anti-icer to the snow and ice maintenance program will support this objective because it is far more efficient to prevent the ice-pavement bond than it is to remove it after it has formed.[3]

Chapter 5 Recommendations

- The current practice of using calcium chloride mixed with brine is functional and remains the most cost-effective option. Calcium chloride is fast-acting and works in temperatures as low as -25 degrees Fahrenheit.
- The research team also recommends FreezGard Cl Plus or Ice Ban 305 as potential substitutes for calcium chloride.
- FreezGard Cl Plus is 1.6 times as effective as calcium chloride at 1.5 times the cost. It contains 30% magnesium chloride and a sulfate additive that acts as a corrosion inhibitor. Its working temperature is about zero degrees Fahrenheit, which is well below Kentucky's average low temperature in winter.
- Ice Ban is 1.1 times as effective as calcium chloride and 1.25 times the cost. Its working temperature is -67 degrees Fahrenheit. Ice Ban 305 contains 25% magnesium chloride as well as corn starch. The corn starch thickens the brine solution, allowing it to remain suspended near the road surface longer. This may reduce costs associated with reapplication of ice melters.
- FreezGard Cl Plus and Ice Ban 305 both function with the existing application equipment and storage facilities. They could be easily integrated in KYTC's winter maintenance program.
- Previous research indicates that the SHRP-based laboratory undercutting test is an adequate substitute for evaluating performance in the field. Nevertheless, field testing is strongly recommended before large-scale implementation.

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Appendix A Survey Results

	MSHA	Montana DOT	North Dakota DOT	Ohio DOT	Ontario	Tennessee DOT	Virginia DOT (District)	Washington DOT	West Des Moines, IA	Wisconsin DOT
Chemicals For Anti-Icing or Prewetting	Brine, MgCl2	Brine, MgCl2, KAc	Brine, KAc, Beet Juice	Brine	Brine, CaCl2, MgCl2, KAc	Brine, CaCl2, CMA, Potato		Brine, CaCl2, MgCl2	Brine, CaCl2, Beet Juice	Brine, CaCl2, MgCl2, Beet Juice
Use Blends?	Yes, in-house	Yes, in-house and commercial	Yes, in-house	Yes, in-house and commercial	Yes, commercial	Yes, in-house	in-house	Yes, in-house and commercial	Yes, in-house	Yes, in-house and commercial
Commercial Products Listed		Shield GLT		Agua Salina and Beet Heet products	Our area maintenance contractors buy commercial blends as they have some additives to suppress freeze point temperatures. They buy their own products. The ministry does not supply products.			Meltdown Inhibited (30% concentration of MgCl2) and Calcium		Thawrox, Clear Lane, Arctic Clear Gold, BioMelt AG 64, IceBite 55, Iceban, M50, Freezeguard, Caliber, Geomelt, Icestop
In-House Recipe	Brine 80%, MgCl2 20%	mix 95% brine with 5% Shield GLT for corrosion inhibitor buy MgCl2 with corrosion inhibitor added	We generally blend 80 salt brine with 20% beet juice at all location. And in every tank. This prevents the plumbing from freezing and breaking			Anti-icing: 94% brine, 6% CaCl2 or 94% brine, 6% potato juice, salt application 5 to 8 gallons of CaCl2 to 2,000 lbs of salt	80-90% NaCl, 10-20% calcium or mag		Brine 90, Beet Juice 10	In Wisconsin, our counties are our winter service providers. The counties have the choice of which products or blends to use. There is a large variety of projects used and some counties change products if the performance or cost becomes a factor
Experience?	We use this blend when temperatures are forecasted to be in the single digits or below	PNS Tests these products and I believe they may have been involved in formal research	no response	link provided	It is 1/20 Area Maintenance Contract areas and it is based on low bid after field testing various products.	TDOT has tested for several years and now the blends listed are listed in the TDOT Winter Operations Guidelines and are dependent upon temperature/ weather conditions.	Contact		Contact	
Evaluation?	No	No	Yes	Yes	Yes	No	No	No	Yes	No
Decision process	Research project	PNS QPL and low bid	We were having issues with plumbing cracking -30 degree temperatures. By blending with a percentage of beet juice we no longer experienced the cracking problems. And, we obviously new it would work better on the road. The eutectic is -18 degrees	Marketing	Field testing	Field testing	Field testing	Field testing	Field testing	Field test and sales visit

	MSHA	Montana DOT	North Dakota DOT	Ohio DOT	Ontario	Tennessee DOT	Virginia DOT (District)	Washington DOT	West Des Moines, IA	Wisconsin DOT
Cost	It cost us 15 cents a gallon to make salt brine and 1.09 dollars per gallon to have liquid mag delivered. Blend cost $0.34/ gallon	Brine $0.45 per gallon, MgCl2 $0.90 per gallon depending on delivery point (MgCl2 mixed with inhibitor, no brine)	We did the math a while ago and I'm trying to remember off the top of my head but it was like 28 cents per gallon. (this is the cost of the blended brine and beet juice)	Contact	Calcium Chloride at $0.07 to $0.33 per littre ($0.20 - 0.97 USD per gallon). Magnesium Chloride at $0.199 to $0.35 per liter ($0.58 to $1.02). Brine (NaCl) at $0.046 to $0.79 per liter ($0.13 to $2.31). Liquid Potassium Acetate at $1.65 to $2.431 per liter ($4.83 to $7.12)	SaltBrine $.08 per gallon (made in house), Calcium Chloride $.85 per gallon delivered, Potato Juice $2.48 per gallon delivered "Brine/ CaCl blend is $0.12 / gallon Potato juice/ brine blend is $0.20 / gallon"	Contact	MeltDown Inhibited is $177 per ton or about $0.96 per gallon	Contact	Spreadsheet provided
Comments	Use only for pre-wetting and treating hardpack, not anti-icing and only for below 10 degrees.	Potassium Acetate on 1 bridge Shield GLT is purely used for corrosive protection	It is smelly and sticky. May track into buildings. We have heard comments from motorists about getting a residue on the windshield. We may have had a few issues with clogging early on when we first started using the product years ago, but not getting any complaints. We may have adjusted the equipment with straight stream nozzles that we don't have those issues anymore. There is some foaming issues when mixing so we use an anti-foaming agent. We also bottom fill so you are pushing the material through liquid. If you top fill and splash the material into a tank, you will get foaming. The operators really like the lower working temp of the liquid so we find ways to make it work. All tanks all across the state are mixed with beet juice. We store the beet juice in 16,000 gallon tanks. It is always mixed 50/50 with salt brine when delivered and pumped into storage tanks. It is delivered by the tanker load as a concentrate. We typically blend it to 80/20 salt brine/beet juice when delivered into our outlying tanks in the sections for use in the field. We recirculate the tanks on a weekly basis to keep solids suspended.				Allen's district frequently uses 5-10% CaCl2/90-95% Brine for anti-icing and against the barrier wall to burn what may refreeze and hard pack snow. Have gone up to 20% for this. Depends on forecast temp./ They add CaCl2 right before application so the blend doesn't sit to mitigate the "mayo" effect. Pre-wet with straight CaCl2. Northern VA district uses 100% MgCl2 for anti-icing	Calcium Chloride with Boost, Brine with Inhibitor		

Appendix B Full Laboratory Methodology

Based on SHRP2 H-205.6 test. Designed to test the ability of a deicer to melt ice at the interface between a layer of ice and a pavement substrate.

1. Mix and cure mortar mix substrate (“Quikrete”).
   - Used 4 pints of tap water to each 50 pound bag, mixed according to directions.
   - Mold consists of a plastic Rubbermaid tray 6”x9”x2”deep, lined with parchment paper. The bottom surface of mold becomes the top surface of testing substrate.
   - Let cure for one full day before use.

2. Freeze ice on substrate using bottom-up technique:
   - Create barrier using plastic form (3D printed) and latex caulk.
   - (When placing barrier leave room for ruler to be placed on top of concrete next to barrier.)
   - Freeze dry substrate at 14°F.
   - Contain pre-chilled, distilled, filtered water on surface of the substrate within the barrier to yield 1/8” thick layer.
   - Place a cold metal plate (14°F) underneath the pavement substrate.
   - Maintain the air temperature at 28 degrees while the water freezes.
   - Cover the water with plastic sheeting. This prevents dust from getting into the ice and keeps the surface a little warmer so that the bottom-up technique can be employed.
   - If it freezes too quickly and is cloudy or contains air bubbles, heat the top of the ice with a very gentle indirect heat source so that the top half is water and the bottom half is ice, and then re-freeze. May repeat several times.
   - The ice must be completely uniform and clear before proceeding with the next steps.

3a. Form cavities in ice using a warm aluminum rod and a syringe:
   - Use aluminum rod with a nominal diameter of 5/32” (found at hardware store) and place rod in 100mL water warmed to ~150°F.
   - Press warmed aluminum rod vertically into surface of ice, press with moderate pressure for 3 to 4 seconds. Can be extended as needed in order to ensure cavity extends all the way down to the pavement substrate.
   - Use 5mL plastic syringe with plastic tip (diameter 4.064mm) to extract melted water from cylindrical cavity.
   - Create cavities in sets of 5; each specimen should accommodate three sets of 5 cavities, with cavities about 4cm apart.

3b. Combine liquid additive and dye.
   - Add liquid deicer to vial of dye (15-20mg).
   - Cool to test temperature or the lowest temperature at which the deicer remains a liquid.
   - Gently agitate this combination regularly during testing to make sure the dye does not separate and that solids do not precipitate out of solution.

4. Place anti-icers within ice cavities.
   - With a pipetting system, place a 30-microliter quantity of deicer in each of the 5 cavities.
   - This step must be performed quickly and within the cold room.

5. Take pictures of the melting process.
   - Set up tripod directly over substrate so that the camera has vertical straight-on view of the ice surface.
   - Place ruler on the concrete substrate outside of the plastic barrier.
   - Take pictures of the substrates at 0, 2, 4, 6, 8, 10, 15, 20 and 30 minutes.
   - Do not move the camera or substrate during this process.

Appendix C Vendor Quotes

IBG MAGIC of KENTUCKIANA
1001 West Kentucky Street, Bldg C1
Louisville, KY 40210

Proposal

Date	Estimate #
6/2/2021	218007

TO:

Erin Lammers

Description	Qty	Rate	Total
Ice B Gone Liquid - Gallon	4,500	3.00	13,500.00
*Pricing is estimated for budget purposes			
Sales Tax		6.00%	0.00

Phone #	Fax #	E-mail	Total
(502) 568-5566	(502) 568-6295	bill@minorandcompany.com	$13,500.00

Please note that all quotes provided are voided after 30 days from date of quote. Thank you!

Please sign and email/fax to office!

Customer Date

SCOTWOOD INDUSTRIES, LLC

SWI

12980 Metcalf Avenue,
Suite 240
Overland Park, KS
66213

PH: 800-844-2022
FX: 913-851-3553
Email: dpratt@scotwoodindustries.com
Cell: 660-605-1390

Date: 05/26/2021

QUOTATION

To: Mr. Erin Lammers

Kentucky Transportation Cabinet

Cell: 920-889-9995

Email: erin.lammers@uky.edu

Product Quoted	*4,500 gal min.	Delivery Locations 820
Ice Ban (84:16)	$1.81/gal **Delivered Only**	Frankfort, KY

Product Quoted	*4,500 gal min.	Delivery Locations
FreezGard Zero CI+ Magnesium Chloride Solution w/ Corrosion Inhibitor	$1.285/gal **Delivered Only**	Frankfort, KY

- Drop charge of $85.00 after the first drop on split load deliveries.
- Pricing does include fuel surcharge.
- Demurrage is $85.00 per hour after the first hour.
- Pricing does not include sales tax.
- Pricing is subject to change.
- Terms net 30 days.
- Weekend/Holiday delivery fee is not included in the above pricing. If required a different price will be calculated.
- Charges will apply if truck is turned around, once in transit.

* Pricing only applies to orders meeting the minimum number of gallons, which is per truckload. If the minimum number of gallons per truckload is not met, a different price will be figured and will apply to the less-than-minimum quantity shipment.

Quotation Effective: May 26, 2021

Quotation prepared by: Doug Pratt ______________________

Emailed quote from SNI Solutions, Geneseo, Illinois.

Per you direction , I have tried to anticipate our capability , and costs out of our Evansville ,Ind. Facility . As this is the closest to your target , for cost purposes , it has the capacity for delivery , to the Frankfort , KDOT facililty.

Cost for Biomelt AG-64 – 4500 gal load – delivered to One site : $ 2.10 @ Gal .

For your review - : I believe the majority of the use will be a 20-80 blend . 20% Bio AG-64 (2 gals)- At $ 2.10 / 80% NaCl Brine – 23 ½ % - (gals) – at a average of $ .20 @ gal .

At 10 gals the cost is $ 5.80 – or .58 Cents per gal for a 20/80 blend . add .10 @ gal for tanks – labor etc. and the real # is .68 Cents @ gall .

The recommended use is 30 -40 gals @ lane mile as a anti - icer . I like 40 Gals , as the cost is $ 27.20 @ lane mile , and 32 gals are NaCl which is about 65 # of salt @ lane mile . This mixture inhibits the corrosiveness of the Brine by about 60% , and the effective temperature for use is depressed to -20-25 F .

This allows for preparation of surfaces , in temperatures that cannot be treated with straight Brine . this same Blend can be used as a pre-wet agent at 8- 10 gals @ ton at the spinner or in the auger .

The AG-64 – is designed to be applied directly to surfaces and bridge decks , as a anti- and as a de-icer down to -40 F . As a Anti –icer the rate is 40 gplm (gals @ lane mile) – as a De-icer the rate is 80 Gplm (for deicing we calculate the dilution factor – in creating water from the frozen residue on the post plowed surface) This format allows for public safety with no corrosiveness to the road surfaces or bridge structures , and with a bio-degradable material that is renewable and sustainable .

If I can be of service , as this research is continuing , please contact me at any time .

As we have been unable to introduce this proven product in the past directly to the KDOT , I appreciate this opportunity to have it considered for the benefit of the State of Kentucky , as it has been utilized in the State of Illinois , for over 4 years , with increasing volumes , in surrounding states at the County and municipal level. The State of Minnesota has approved this product under the label of Geomelt – Gen 3 , as it was introduced over ten years ago , and uses it in several districts in Northern Minnesota , due to its low temperature capability .

The Difference of all the inferior products , and ours , is that we are the authority on Organic accelerators , we make all of our products , we consult , at no charge , to assist in the clients use , and execution of proven winter procedures, and I guarantee the performance of our products – especially AG-64 to perform as presented , or the Client does not have to pay for it . No one in the industry – gives this guarantee.

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Office: (309) 944-3168
Toll Free: 888-840-5564

Appendix D Product and Safety Data Sheets

IBG MAGIC of KENTUCKIANA

1001 W. Kentucky Street, Bldg. C-1
Louisville, Kentucky 40210-1325

Office: 502-568-5566
Fax: 502-568-629

IBG MAGIC
SPECIFICATIONS

<u>PRODUCT SPECIFICATIONS:</u>

Manufacturer - Sears Ecological Applications Company, LLC

Produce Use - Additive to deicing rock salt and salt brine for improved winter road maintenance

Application Rates -	
Rock Salt: gallons / ton to typical gradation road deicing salt	8 gallons
Salt Brine: addition by volume	5 - 20%
Chemical Components -	
Distillers Condensed Soluables*	40 - 50%
Magnesium Chloride	50 - 60%
Specific Gravity	1.22 - 1.29
Ph	3.5 - 4.5
Freezing Point in liquid form	-45 degrees F
Freezing Point when added to rock salt	-35 degrees F
Color / Appearance	Brown Liquid
Odor	Pleasant
EPA Recognition**	DfE

* Distillers Condensed Solids are derived from the distillation process of vodka and rum which are naturally noncorrosive and reduce the corrosive potential of deicing chlorides.

**EPA allows safer products to carry the Design for the Environment (DfE) label. This mark allows consumers to quickly identify and choose products that can help protect the environment and are safer for families.

Effective 12-15

Product Data Sheet

EarthFriendlyChemicals
incorporated

ICE BAN® 305

Ice Ban, the Original Organic Inhibitor

In 1995 we started the revolution by introducing organically inhibited chloride based anti-icing / deicing fluids. Combining a corn based inhibitor with a liquid chloride solution, this patented (U.S. Patent No's. 5,635,101 & 5,965,058) anti-icing, deicing liquid provided superior performance at an affordable price. First introduced as a series of blends based on one inhibitor, the organic inhibitors have now been engineered to address the most significant applications encountered by today's snow and ice control professionals.

Ice Ban 305 is designed as an anti-icing and deicing liquid for sensitive environmental areas where significant reductions in phosphorus and nutrients are necessary to protect a fragile eco-system. Ice Ban 305 provides the protection you require with the performance you demand. Ice Ban 305 is a clear, colorless Magnesium Chloride based liquid delivering excellent performance, extremely low corrosion rates and a depressed freeze point of –67° F. All of these attributes add up to a product designed to maintain high service levels for the roads and the environment.

The included tables illustrate the engineered chemical and physical characteristics of Ice Ban 305.

Chemical & Physical Analysis

Component	Units	Typical	PNS Limit
$MgCl_2$	%	25	25
Phosphorus	ppm	<0.05	25
Cyanide	ppm	<0.05	0.2
Arsenic (As)	ppm	<1.0	5
Copper (Cu)	ppm	<0.1	0.2
Lead (Pb)	ppm	<0.50	1
Mercury (Hg)	ppm	<0.02	0.05
Chromium (Cr)	ppm	<0.50	0.5
Cadmium (Cd)	ppm	<0.05	0.2
Barium (Ba)	ppm	<0.50	10
Selenium (Se)	ppm	<1.0	5
Zinc (Zn)	ppm	0.4	10
pH (1:4 Solution)		8.3	6-10
Corrosion Rate	%	17.1	<30

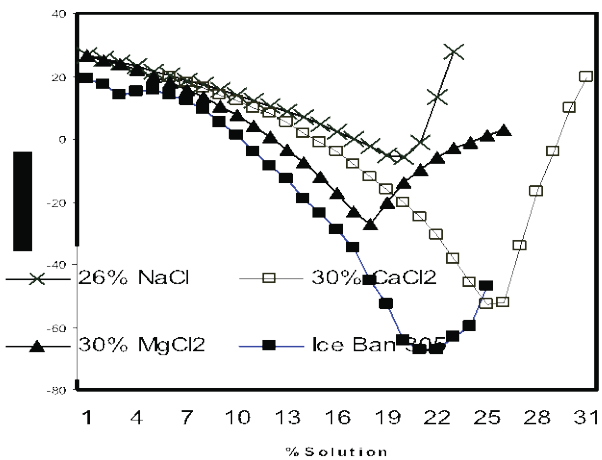
Component	Units	Typical
Specific Gravity	SGU (at 20°C)	1.276
TTL Settleable Solids (V/V)	%	≤1
Solids Passing #10 Sieve (V/V)	%	≥99
Freeze Point	-	-55° C / -67° F

EARTH FRIENDLY CHEMICALS, INC.
2585 Horse Pasture Rd, Suite 201, Virginia Beach, VA 23453
Tel (800) 753-1548 ● Fax (757) 802-9531 ● www.efchem.com

ICE BAN® 305

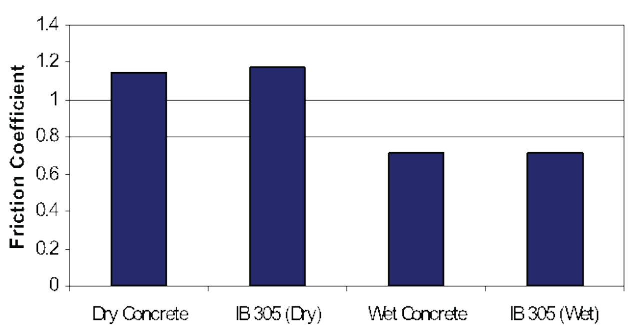
Increased Working Range, Decreased Maintenance Costs

The phase curve diagram below illustrates the increased effective range that Ice Ban 305 offers over 30% Magnesium Chloride, 30% Calcium Chloride and 26% Sodium Chloride (Salt). Ice Ban 305 has a eutectic point of –77° F at a 21% Magnesium Chloride concentration solution. The increased working range of Ice Ban 305 greatly reduces the likelihood that the melted snow and ice will re-freeze between applications, reducing the need for excess treatments and additional trips by workers.



Safe for the Environment, Safe for the Public

Testing performed by Forensic Dynamics, Inc. in July 2001 on the friction characteristics of Ice Ban 305 show that a concrete surface treated with Ice Ban 305 had a friction coefficient slightly less than that of concrete wetted with water. When dry, the Ice Ban treated surface has a friction coefficient higher than that of dry concrete. In fact, Ice Ban 305 was one of the highest performing Magnesium Chloride based products ever tested.



EARTH FRIENDLY CHEMICALS, INC.

2585 Horse Pasture Rd, Suite 201, Virginia Beach, VA 23453

Tel (800) 753-1548 • Fax (757) 802-9531 • www.efchem.com

Product Data Sheet

9900 West 109th Street – Suite 100
Overland Park, Kansas 66210
Phone 800-755-7258 Fax 800-359-7258

FREEZGARD® CI PLUS

PRODUCTION LOCATION

Ogden, Utah

PRODUCT DESCRIPTION

Produced naturally from the Great Salt Lake, FreezGard® CI Plus is specially formulated for deicing and anti-icing. It remains active (liquid) at cold temperatures while minimizing precipitates down to zero degrees Fahrenheit. FreezGard Zero is a tan to light amber liquid with a density of approximately 185 gallons per ton. A corrosion inhibitor has been added to reduce the corrosion rate.

Typical Analysis			Typical	Range
Magnesium Chloride	$MgCl_2$	(%)	30.3	26 – 34
Sulfate	SO_4	(%)	0.9	0.1 – 1.7
CI Plus Inhibitor		(%)	2.0	1.8 - 2.2
Water	H_2O	(%)	66.8	65 - 70

METHOD OF ANALYSIS

All analyses were performed by Compass Minerals Quality Control personnel. Copies of test reports are available upon request.

APPLICATION AND STORAGE

This liquid $MgCl_2$ product in storage should be agitated regularly to minimize precipitation of undesirable solids/crystals. Application equipment should be washed daily with water. Storage equipment should be rinsed with water to prevent buildup of solids. Aluminum storage tanks or hauling equipment should not be grounded. Over application of $MgCl_2$ may result in unusually slippery road surfaces and should be avoided.

CORROSION INHIBITOR

The CI Plus Corrosion inhibitor is a proprietary formulation that is optimized to significantly reduce metal corrosion.

PHYSICAL PROPERTIES

Specific Gravity	1.29 +/- 0.03
pH (5% Solution)	7 - 9
Weight	10.5 - 11.2 lbs./gallon

Product Description and Codes	UPC code	Product Code
Bulk		21903

1 Nov 2015

Information herein is intended to be indicative and not to be interpreted as a specification and no warranty is given

SNI SOLUTIONS
GENESEO, IL
ENVIRONMENTAL CHEMICAL CONTRACTOR

888-840-5564

Safety Data Sheet

SECTION 1 – Identification

Product: BIOMELT® AG64 anti-icing/deicing fluid

Chemical Name: Trade Secret

Formula: Proprietary

Manufacturer: SNI Solutions

24-Hour Emergency Assistance: **888-840-5564**

SECTION 2 –Hazard(s) identification

NFPA Identification - BIOMELT® AG64 Health – 1, Fire – 0, Instability - 0.

NFPA – Hazard Identification: This system identifies the hazards in three categories: Health, Flammability and Reactivity and indicates the order of severity ranging from 4 indicating a severe hazard to 0 indicating no special hazard.

SARS-EPA SARA Title III Hazard Categories: 1-Fire Hazard, 2-Sudden Release of Pressure, 3-Reactive, 4-Immediate (Acute) Health Hazard, 5-Delayed (Chronic) Health Hazard.

SECTION 3 – Composition / information on ingredients

Composition : Trade Secret	Ingredients : Trade Secret

SECTION 4 – First Aid Measurers

Emergency and First Aid Procedures:
Ingestion: If ingested seek medical supervision.
Skin Contact: Wash skin with water and mild soap. If irritation occurs, seek medical attention.
Eye Contact: Flush eyes with plenty of water for 30 minutes. Get medical attention if warranted.
Inhalation: Remove to fresh air. Seek medical attention if irritation persists.

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SECTION 5 – Fire – Fighting Measurers

Flash Point (Method Used): Not applicable
Flammable Limits: LEL – not applicable UEL – Not applicable
Special Fire Fighting Procedures: Wear proper fire - fighting equipment
Unusual Fire and Explosion Hazards: None

SECTION 6 – Accidental Release Measurers

Material is Released or Spilled: All spills should be contained and picked up with earthen or other absorbent material and placed in suitable container.
Waste Disposal Method: Dispose per approved area regulations.

SECTION 7 – Handling and Storage

Precautions Handling and Storing: Spilled material may be slippery. Clean up spills completely before walking in the area of spillage.
Other Precautions: None

SECTION 8 – Exposure Controal / Personal Protection

Personal Protective Equipment: Protective clothing, gloves and safety eyewear protection are not required, but recommended. Use appropriate NIOSH-approved respirator when needed. Respirator selection must be based on contamination levels found in the work area. Comply with OSHA standards 29 CFR 1910.134 Respiratory Protection and 29 CFR 1910.1000 Air contaminants Permissible Exposure Limits. Eyewash and Safety Shower should be available. Follow good housekeeping and manufacturing practices.

Ventilation: Use general or local exhaust ventilation to meet OSHA PELS or ACGIH TLV requirements.

SECTION 9 Physical and Chemical Properties

Boiling Point (F): Not Available	**Specific Gravity (H^2O=1):** ~ 1.28
Vapor Pressure (mmHg): Not available	**Evaporation Rate (n-BuAc=1):** Not available
Vapor Density (Air=1): Not available	**Melting Point:** Not available
Solubility in Water: Complete	**pH:** ± 6.0 – 8.5
Appearance and Odor: dark aqueous solution; sweet odor	

SECTION 10 – Stability and Reactivity

Stability: Stable
Conditions to avoid: None
Incompatibility: (Materials to Avoid): May corrosive to light metals.
Hazardous Decomposition Products: Thermal decomposition may produce oxides of carbon.
Hazardous Polymerization: Will not occur.

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SECTION 11 Toxicological Information

Product Ingredients not listed in the National Toxicology Program (NTP) Report on Carcinogens or has been found to be a potential carcinogen in the International Agency for Research on Cancer (IARC) Monographs, or by OSHA.
Route(s) of Entry: Inhalation – none. Skin – unlikely. Eyes – yes. Ingestion – unlikely.
Carcinogenicity: NTP – no. OSHA –no.
Threshold Limit Value: See Section II
Acute Oral Toxicity (rat): Low acute oral toxicity; LDL50 for rats is >5 g/kg.
Skin Contact: May cause irritation.
Eye Contact: May be irritating to eyes.
Inhalation: None
Effects of Overexposure: Acute signs and symptoms as listed.

SECTION 12 – Ecological Information

Non Mandatory – Regulated by Other Government Agency.

Investigate Local, State and Federal Regulations.

SECTION 13 – Disposal Considerations

Non Mandatory – Regulated by Other Government Agency.

Investigate Local, State and Federal Regulations.

SECTION 14 – Transportation Information

Non Mandatory – Regulated by Other Government Agency.

Investigate Local, State and Federal Regulations.

SECTION 15 – Regulatory Information

Non Mandatory – Regulated by Other Government Agency.

Investigate Local, State and Federal Regulations.

SECTION 16 – Other Information

SNI Solutions – SDS Document review and approval date: 06-20-14

The information contained herein is furnished without warranty of any kind. Employees should use this information only as a supplement to other information gathered by them and must make independent determinations of suitability and completeness of information from all sources to assure proper use of these materials and the safety and health of employees.

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